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SUMMARY REPORT  
OF  
WORK PERFORMED  
UNDER  
CONTRACT DAAA-21-67-C-0217

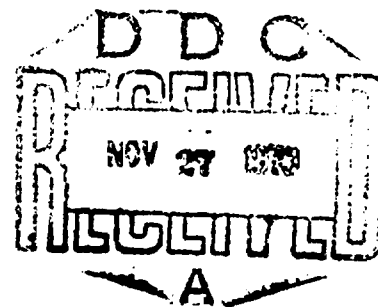
FOR

PICATINNY ARSENAL  
DOVER, NEW JERSEY

CONTRACT DAAA-21-67-C-0217

BY

AMMANN & WHITNEY  
CONSULTING ENGINEERS  
NEW YORK, NEW YORK



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July 1970

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### ACKNOWLEDGEMENT

The successful completion of this project is the result of the efforts of the staff of the Special Structures Department of the firm of Ammann & Whitney. The work was accomplished under the general direction of Mr. Edward Cohen, Partner-in-Charge, and the immediate supervision of Mr. Norval Dobbs. Technical assistance was received from Messrs. Michael Dede, Edward Laing and Joseph Porcaro.

This project was performed under the supervision of the Ammunition Engineering Directorate, Picatinny Arsenal, Dover, New Jersey. Valuable assistance throughout the project was furnished by Messrs. Richard Rindner, Leon Saffian and Stanley Wachtell of Picatinny Arsenal, who monitored the Supporting Studies Program.

## SUMMARY

The purpose of this report is to document in one volume the sources of data developed under Contract DAAA-21-67-C-0217.

The primary objective of this report is to familiarize interested personnel with the type of data developed and to indicate the technical documents in which a full description of the data may be obtained. This is accomplished by indicating the report name, author (where applicable), an abstract of the report contents, and where the report may be obtained.

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Part I

PURPOSE AND OBJECTIVES

The purpose of this report is to document in one volume the sources of data developed under Contract DAAA-21-67-C-0217.

The primary objective of this report is to familiarize interested personnel with the type of data developed and to indicate the technical documentation in which a complete description of the data can be obtained.

The secondary objectives of the report are as follows:

1. To give a brief summary of the material developed.
2. To indicate its applicability to past and future projects.
3. To indicate where the data has previously been disseminated.

## Part II

### BACKGROUND

Picatinny Arsenal has recently completed for the Armed Services Explosives Safety Board an extensive systematic testing program which has led to the establishment of design standards to be employed in the engineering of new explosive-storage and explosive-manufacturing facilities. These standards are contained in the tri-service design manual entitled "Structures to Resist the Effects of Accidental Explosions". Ammann & Whitney, under contract to Picatinny Arsenal provided technical assistance in the development of the structural design criteria and in other aspects of the program.

## Part III

### DATA DEVELOPED

#### 1. Introduction

The data developed under Contract DAAA-21-67-C-0217 can be classified under four major topics, namely: (1) preparation of test plans, (2) summary of test results, (3) evaluation of new and/or existing explosive-manufacturing or storage facilities, and (4) design and/or analysis of protective structures. Most of the material contained in the reports prepared in connection with the first two topics has been used in the development of design procedures whereas the information presented in connection with the last two topics can be considered as the application of the data obtained from the tests. Initial distribution of the test plans was limited to test personnel while the reports prepared under the other three topics had wider initial distribution.

In the following description of the individual reports, the report title and authors (where individuals are cited) are given in addition to a short abstract of the report contents. Further distribution of the reports is also cited. However, some of the reports are no longer in existence or their distribution is restricted and, therefore, further distribution of these reports cannot be made. This limitation of further distribution will be so noted in this report.

#### 2. Test Plans

##### a. Test Plan No. 1

(1) Title: Testing Plan for Evaluation of the Dynamic Properties of Laced Reinforced Concrete Slabs.

(2) Abstract: This report describes the test set-up, test procedures and test specimens to be used in the dynamic and static testing of four laced reinforced concrete slabs. The tests were performed by the U.S. Naval Civil Engineering Laboratory (NCEL), Port Hueneme, California. The results of this test program were reported in Reference 1.

(3) Availability: No longer available.



b. Test Plan No. 2

(1) Title: Testing Plan for Evaluation of the Use of Blast Attenuating Materials Used in Combination with Reinforced Concrete Slabs.

(2) Abstract: This report describes the test set-up, test procedures and test specimens to be used in high explosive energy absorption tests of cellular concrete when used as coating material for reinforced concrete slabs (both laced and unlaced) and as sandwich material for laced reinforced concrete composite slabs.

A total of fifteen slabs were tested some of which were utilized as standards to evaluate the energy absorption capacity of the cellular concrete. These standards were either plain laced reinforced concrete slabs or laced composite slabs with sand as the filler material. The results of the tests were based upon slab deflections and/or pellet velocity records obtained during the performance of the tests. The tests were performed at the Waterways Experiment Station, Jackson, Mississippi. The results of this test series were reported in Reference 2.

(3) Availability: No longer available.

c. Test Plan No. 3

(1) Title: Testing Plan for Static Slab Tests.

(2) Abstract: This report describes the test equipment, test specimens and test procedures to be used in connection with static testing of reinforced concrete slabs. A total of sixteen slabs were originally scheduled to be tested. These slabs included both laced and unlaced elements as well as cantilever and fully restrained (against sliding and support rotation) specimens. The results of these tests were summarized in Reference 4.

(3) Availability: No longer available.

3. Summary of Test Results

a. Report No. 1

(1) Title: Establishment of Safety Design Criteria for use in Engineering of Explosive Facilities and Operations - Supporting Studies, January-December 1966 - Report No. 9 - Picatinny Arsenal Technical Report 3594, June 1967.

(2) Authors: R. Rindner, S. Wachtell and L. Saffian.

(3) Abstract: This report summarizes the work performed in connection with Picatinny Arsenal's Supporting Studies Program during 1966. The work contained in this report in which Ammann & Whitney has participated includes:

- (a) Performance of model reinforced concrete slab tests.
- (b) Performance of model and full-scale bay tests.
- (c) Performance of modified Phase C-13 cubicle test.
- (d) Development of design charts.
- (e) Feasibility study for increasing the explosive capacity of an Air Defense Command (ADC) Multi-Cubicle Magazine.

Part of the data summarized in this report is more fully described in other reports.

(4) Availability: Defense Documentation Center.

b. Report No. 2

(1) Title: Establishment of Safety Design Criteria for Use in Engineering of Explosive Facilities and Operations - Report No. 10 - Blast Pressures and Impulse Loads Produced by Explosions in Cubicle Type Structures - Picatinny Arsenal Technical Report 3604, May 1967.

(2) Authors: E. Cohen, N. Dobbs and R. Rindner (coordinator)

(3) Abstract: Contained in this report is a series of charts which define the average impulse loads acting on the interior surfaces of a cubicle type structure as a result of an explosion within the structure. The charts were developed from semi-empirical data obtained from structural steel cubicle tests and concrete component tests. The charts were developed for a variety of structure dimensions, charge weights and locations.

In addition to close-in blast effects, this report contains the magnitude of pressures which will leak out of the cubicle onto the ground surface exterior of the structure containing the explosion. The magnitude of these pressures was obtained from full scale cubicle tests, the results of which are contained in Reference 3.

(4) Availability: Defense Documentation Center.

c. Report No. 3

(1) Title: Establishment of Safety Design Criteria for Use in Engineering of Explosive Facilities and Operations - Supporting Studies, January-December 1967 - Report No. 11 - Picatinny Arsenal Technical Report 3712, September 1968.

(2) Authors: R. Rindne , S. Wachtell and L. Saffian.

(3) Abstract: Summarized in this report is the work performed in connection with Picatinny Arsenal's Supporting Studies Program during 1967. The work contained in this report in which Ammann & Whitney has participated includes:

- (a) Performance of model reinforced concrete slab tests.
- (b) Performance of model and full-scale bay tests.
- (c) Preparation of draft of design manual.
- (d) Preparation of technical reports and papers pertaining to the Safety Design Program.
- (e) Assistance in the design of several explosive facilities.
- (f) Performance of tests on blast attenuating materials.

The data given in this report is described in more detail in other reports which will be discussed later in this report.

(4) Availability: Defense Documentation Center.

d. Report No. 4

(1) Title: Report of Transverse Bending Tests Made Upon Reinforced Concrete Slabs.

(2) Author: C. W. Thurston.

(3) Abstract: This report describes the results of twelve static slab tests; the purpose of which was to evaluate the response of laced reinforced concrete slabs to statically applied loads. This response was evaluated in terms of maximum

plastic rotation. Both cantilever and one-way spanning elements were used in these tests. Deflections at predetermined locations along each slab as well as the rotation at each end of the slab were recorded and tabulated.

At the present time, an analysis of the test results is being performed. The results of the analysis in addition to the data contained in this report will be presented in a subsequent report now under preparation.

(4) Availability: Restricted distribution.

4. Explosive Facility Design and Investigation

a. Report No. 1

(1) Title: Investigation of Hill Air Force Base Hazardous Test Facility.

(2) Abstract: At the request of the Commanding Officer, Hill Air Force Base, Utah, an investigation was made to develop conceptual layouts of an explosive hazardous test facility to contain the blast and fragment output of 3 pounds of H.E. The facility consisted of three new cells to be constructed within an existing non-hardened building. A total of five schemes were investigated, three of which would provide protection for operating personnel while the other two were designed to prevent propagation of explosion. The results of this investigation were reported in Reference 2.

(3) Availability: Defense Documentation Center.

b. Report No. 2

(1) Title: Blast-Resistant Analysis of Building No. 800 - Picatinny Arsenal.

(2) Abstract: This report summarizes the results of an analysis to determine the effects produced by an explosion equal to 100 pounds of H.E. within Building No. 800. In addition, this study includes an evaluation of the quantity of explosive which would be considered safe for the operating personnel within the structure.

(3) Availability: Restricted distribution.

c. Report No. 3

(1) Title: Inspection of Construction of Ammunition Maintenance Facility - Letterkenny Army Depot.

(2) Abstract: This report contains the results of an inspection trip to determine whether the construction of the Letterkenny Facility was in compliance with the design. The inspection was limited to the structural portions of the facility. The results of the inspection were reported to the Office of the Chief of Engineers, Corps of Engineers, under whose direction the original design and construction were performed.

(3) Availability: Restricted distribution.

d. Report No. 4

(1) Title: Concept Study of the Proposed Modification of Building 5840.

(2) Abstract: Summarized in this report are the results of an investigation to determine the practicality of modifying Building 5840, Edgewood Arsenal, Maryland, to prevent propagation of explosion and to protect personnel as a result of an explosion as large as 20 pounds of H.E. in one of six test cells. The conceptual study included an evaluation of using either new reinforced concrete or structural steel cells to provide full protection for personnel whereas new steel cubicles were evaluated to determine their capacity to prevent propagation. The results of this study are presently being prepared for presentation in a Picatinny Arsenal Technical Report.

(3) Availability: Restricted distribution.

e. Report No. 5

(1) Title: Structural Concept Studies for the Proposed Sprint Missile Propellant Production Facility at Radford Army Ammunition Plant.

(2) Abstract: This report describes the conceptual design of Curing and X-Ray Facilities which were proposed for use in the manufacture of the propellant for the Sprint Missile. Construction of these facilities was proposed at Radford Army Ammunition Plant, Radford, Virginia. The curing facility consisted of two buildings containing a total of 33 curing bays. It was anticipated that a total quantity of explosives equal to 3750 pounds would be contained in each cell. The curing buildings

were designed to prevent propagation of explosion from one cell to another. Protection for personnel was not required in the curing facility. However, the X-Ray Facility did involve personnel. Here, the operating personnel would be located immediately adjacent to a test cell containing 4000 pounds of H.E. Full protection for the personnel from the effects of blast, fragments and x-rays was considered in the design. The results of this study will soon be published as a Picatinny Arsenal Technical Report.

(3) Availability: Restricted distribution.

f. Report No. 6

(1) Title: Structural Evaluation of the Preliminary Design of the Theater Reliability Monitoring Facility at Pueblo Army Depot.

(2) Abstract: Contained in this report is the evaluation of the blast-resistant capabilities of the Theater Reliability Monitoring Facility to prevent propagation of explosion between certain adjacent sections of the facility and to provide full protection for personnel and valuable equipment in other parts of the facility. This evaluation was prepared for the U.S. Army Corps of Engineers, Omaha District, and includes recommended changes in the proposed facility layout.

(3) Availability: Restricted distribution.

g. Report No. 7

(1) Title: Structural Instrumentation and Construction Specifications for Simulated Bay Structure for Use in Evaluation of Simultaneity Aspects Regulations of Quantity-Distance.

(2) Abstract: This report contains the recommended specifications for instrumenting and construction of the simulated bay structure used in the evaluation of simultaneity aspects regulation of quantity-distance. Included are deflection gage and photographic coverage of the test. In addition, design drawings including wall dimensions and reinforcement are presented. The results of the construction phase of the structure are covered in Reference No. 2 whereas the results of the structure tests are contained in Reference No. 5.

(3) Availability: Restricted distribution.

h. Report No. 8

(1) Title: Barricade Evaluation Tests.

(2) Abstract: This report describes several barricading methods to be used in conjunction with "Big Papa" tests. However, because of the short period of time involved, the suggested barricading systems could not be included in the tests.

(3) Availability: Restricted distribution.

i. Report No. 9

(1) Title: Cost Effectiveness Studies of Facilities for High-Hazard Explosive Material.

(2) Authors: E. Cohen and N. Dobbs.

(3) Abstract: This report describes some of the studies and tests which have been conducted to reduce construction costs of explosive facilities employing laced reinforced concrete structures. This report was presented as a paper and is contained in the Minutes of the Ninth Explosives Safety Seminar of the Armed Services Explosives Safety Board (Ref. 6).

(4) Availability: Defense Documentation Center.

j. Report No. 10

(1) Title: Design of Ammunition Maintenance Facility for Conventional and Advanced Weapons.

(2) Author: E. Laing.

(3) Abstract: This report presents a discussion of the criteria and concepts associated with siting, design and construction of a maintenance facility serving both conventional ammunition and large solid propellant motors of guided missiles and rockets. This report was presented as a paper at the Ninth Explosives Safety Seminar sponsored by the Armed Services Explosives Safety Board (Ref. 6).

(4) Availability: Defense Documentation Center.

k. Report No. 11

(1) Title: Application of New Design Techniques for High Capacity Protective Barriers - Case Studies.

(2) Authors: E. Cohen and N. Dobbs.

(3) Abstract: This report describes the philosophy and procedures used in the siting and design of several new protective structures. Included in the discussion are methods used for providing protection for personnel and equipment at close-in and far ranges as well as methods to prevent propagation of explosion. This report was presented as a paper at the Tenth Explosives Safety Seminar conducted by the Armed Services Explosives Safety Board (Ref. 7).

(4) Availability: Defense Documentation Center.

l. Report No. 12

(1) Title: Blast Pressures and Impulse Loads for Use in the Design and Analysis of Explosive Storage and Manufacturing Facilities.

(2) Authors: N. Dobbs, E. Cohen and S. Weissman.

(3) Abstract: This paper describes the blast environment associated with both unconfined and partly confined H.E. explosions. Presented are charts and tables which will enable one to define the overpressures and other blast parameters produced by H.E. detonation. This paper was used as the bases for the development of Chapter 4 "Effects of Explosions" of Reference 8 and is presented in Reference 9.

(4) Availability: New York Academy of Sciences, New York, New York.

m. Report No. 13

(1) Title: Design Procedures and Details for Reinforced Concrete Structures Utilized in Explosive Storage and Manufacturing Facilities.

(2) Authors: E. Cohen and N. Dobbs.

(3) Abstract: Described in this paper are methods and procedures which may be used for the design of reinforced concrete structures to resist the effects of H.E. explosions. Discussed are the results of confirmatory tests as well as methods of design and detailing of blast resistant structures. This paper was used as the bases for the development of Chapters 5, 6, 7, 8 and 9 of Reference 8 and is presented in Reference 9.



(4) Availability: New York Academy of Sciences, New York, New York.

n. Report No. 14

(1) Title: Design of Ammunition Maintenance Facility.

(2) Author: E. Laing.

(3) Abstract: This paper describes the procedures used in the design of a standard Ammunition Maintenance Facility as performed by Ammann & Whitney for the Office of the Chief of Engineers, Corps of Engineers, Department of the Army. This paper is presented in Reference 9 of this report.

(4) Availability: New York Academy of Sciences, New York, New York.

o. Report No. 15

(1) Title: Models for Determining the Response of Reinforced Concrete Structures to Blast Loads.

(2) Authors: E. Cohen and N. Dobbs.

(3) Abstract: This paper describes the general method of scaling structures to be used in model-response tests. In addition, a description of several test series are presented which illustrate the application of model theory to reinforced concrete structures. This paper is presented in Reference 9.

(4) Availability: New York Academy of Sciences, New York, New York.

p. Report No. 16

(1) Title: Model Techniques and Response Tests of Reinforced Concrete Structures Subjected to Blast Loads.

(2) Authors: N. Dobbs and E. Cohen.

(3) Abstract: This paper is an up-dated version of Report No. 15. In addition to describing the General Scaling Laws; model design, construction, and test siting used in several model tests are fully described. This paper is presented in Reference 10.

(4) Availability: American Concrete Institute, Detroit, Michigan.

## REFERENCES

1. W.A. Keenan, Strength and Behavior of Laced Reinforced Concrete Slabs under Static and Dynamic Load, Technical Report R620, Naval Civil Engineering Laboratory, Port Hueneme, California, April 1969.
2. R. Rindner, et.al., Establishment of Safety Design Criteria for Use in Engineering of Explosive Facilities and Operations - Summary Studies, January-December 1967 - Report No. 11, Technical Report No. 3712, Picatinny Arsenal, Dover, New Jersey, September 1968.
3. H.M. Richey, Armed Forces Explosives Safety Board Wail Program, Phase C, Tests 1 through 13, Technical Progress Report 346, U.S. Naval Weapon Center, China Lake, California, April 1964, (SECRET RESTRICTED DATA).
4. C.W. Thurston, Report of Transverse Bending Tests Made Upon Reinforced Concrete Slabs, Report No. 2679, Carleton Materials Laboratory of the Department of Civil Engineering and Engineering Mechanics, Columbia University, New York, New York, June 1969.
5. Evaluation of Explosive Simultaneity Tests, NWCTD4720, by URS Research Company for Systems Development Departments, Naval Weapons Center, China Lake, California, May 1969.
6. Minutes of the Ninth Explosives Safety Seminar, Sponsored by the Armed Services Explosives Safety Board, Washington, D.C. 20315, August 1967.
7. Minutes of the Tenth Explosives Safety Seminar, Sponsored by the Armed Services Explosives Safety Board, Washington, D.C. 20315, August 1968.
8. Structures to Resist the Effects of Accidental Explosions, TM5-1300, NAVFAC P-397 and AFM 88-22, Department of the Army, Navy and Air Force, June 1969.

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9. Annals of the New York Academy of Sciences Conferences, Prevention of and Protection Against Accidental Explosion of Munitions, Fuels and other Hazardous Mixtures, Volume 152, Art. 1, October 28, 1968.
10. Proceedings of the American Concrete Institute Model Symposium, SP 24-17, American Concrete Institute, Detroit, Michigan, To Be Published.

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